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Seasonal variation in the rate of radon exhalation from soil in Mysore

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Abstract : Radon exhalation rate was studied in soil near the department of physics, University of Mysore, Mysore Measurements were carried out for 5 days in a month over the period of one year Diurnal and seasonal variations have been followed The observations show that the exhalation rate reach a maximum during afternoon and a low constant during nights Radon exhalation rate was observed very high during summer, and low in winter season During rains the fluctuations were more pronounced The rates have ranged from 3 23 to 8 54 mBq m^{-2} s^{-1} These values are low as compared to the global average The observed low exhalation is attributed to low background concentration of uranium and thorium in the experimental area

Keywords : LLRDS, collection chamber, alpha counting system

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Inhalation of radon progeny has been recognized as being the major contributor to population radiation exposure [1]. Earth scientists have had a long-standing application oriented interest in radon. One of the earliest field application was to use radon survey as a technique for uranium exploration [2]. As uranium mining activities waxed and waned, so did research on understanding the behaviour of radon in nature. But other application for radon investigations, such as the prediction of earth quakes, volcanic eruptions *etc.* [3], kept the interest going at least at minimal levels, even during the periods of decreased mining activity.

Radon/Thoron produced in soil gets released into its void spaces. Although diffusion of radon thereafter is isometric, a net movement in the upward direction, along a concentration gradient is observed [4,5]. The quantitative exhalation from the soil surface depends on geophysical parameters (*e.g.* nature of soil/rock, porosity, humidity, moisture content) and climatological parameters (*e.g.* pressure, temperature, rainfall). Many attempts have been made to quantitatively estimate the radon exhalation rates [6,7] In this study, radon exhalation rates from the soil in Mysore (Karnataka State) region are studied and correlated with the local radiation background. The site chosen for the study was near the Department of Physics, University of Mysore, measurement were made using an accurate technique with "Low Level Radon Detection System (LLRDS)"

The basic scheme of the measurement has the following steps

(i) Collecting the radon exhaled from a known area of soil surface for a given time in a chamber called collection chamber.

(ii) Transfer of a specific fraction of the air from collection chamber to LLRDS.

(iii) Estimation of radon concentration in LLRDS by established procedure [8].

(iv) Calculation of the radon exhalation rate from the radon concentration in the LLRDS chamber and other collection parameters.

The experimental set up is as shown in Figure 1 It consists of a cylindrical metallic vessel of diameter 420 mm and height 270 mm with its open end buried to a depth of 150 mm at the selected location The effective volume of the chamber is 16.6 litres On the top of the chamber, two openings are provided one for connecting a hard rubber bulb which is used for mixing the air for uniformity in the collection chamber for homogenisation before transfer and the other for transferring the air from collection chamber to the LLRDS This tube has a *T* connector to which a pressure gauge is connected

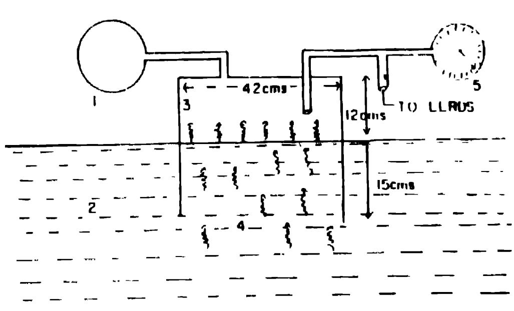

Figure 1. Schematic of experimental set up. 1 Rubber bulb, 2 Earth surfaces, 3 Radon gas collected, 4 Radon gas exhaled from soil, 5 Pressure gauge.

Radon collected for one hour in collection chamber was transferred to a partially evacuated LLRDS. The pressure in the LLRDS before and after the transfer are noted The one hour duration for collection was chosen after a series of preliminary experiments with varying collection time (15, 30, 45, 60, 120, 180 min). The collection for 1 hour was found to be adequate for accurate estimation purposes for this site. Radon concentration in LLRDS chamber was calculated using standardized procedure [8]. Using the radon concentration with LLRDS, the exhalation rate (Radon) from the soil is calculated as

$$R\,(\mathrm{Bq.m^{-2}.S^{-1}}) = \frac{R_n V_c}{(1-P_t)AT_c},$$

R_n – the radon concentration in LLRDS chamber (Bq/m^3)

P_i – the initial pressure inside LLRDS expressed as a fraction of atmospheric pressure,

A – area of exhalation (m^2),

T_i – time of radon collection in (seconds),

V_i – volume of the collection chamber in m^3

Measurements were carried out thrice a day and 5 days in a month over a period of one year. Diurnal variation were measured with the time interval of two hours in a day, in the months of January, March and April. Humidity, ground surface temperature and rainfall were also recorded.

The results of radon exhalation measurements are given in Table 1. It is seen that the exhalation rate is maximum during summer and minimum in winter. Fluctuation is more pronounced in the rainy season. Exhalation rate reduces when precipitation is high and it ceases altogether under soaked ground conditions, since the moisture in the soil tends to hold up radon. As the moisture content of the layers of the soil reduces due to evaporation, the excess of radon collected in the interstitial moisture during the past few days, tends to get released as enhanced exhalation. When the excess water has evaporated radon, the exhalation rate also becomes normal [7]. The exhalation rate is understandably a function of soil porosity which gets modified due to presence of moisture. Effective porosity during these studies could not be determined due to operational constraints.

Table 1. Daily average exhalation rate in different months

Date	Exhalation rates mBq m^{-2} s^{-1}		Rainfall in mm	Average ground temperature in °C
	Daily Average	Monthly Average		
04.03.95	6.22 ± 0.66	7.00 ± 0.71		29
14.03.95	6.67 ± 0.68			29
25.03.95	6.98 ± 0.72			30
30.03.95	8.13 ± 0.79			31
03.04.95	8.14 ± 0.75	7.45 ± 1.04		33
07.04.95	8.66 ± 0.79			32
08.04.94	7.14* ± 1.56		40	31
12.04.94	5.56* ± 1.78		60	29
25.04.95	7.25 ± 0.75			30
30.04.95	7.95 ± 0.54			33
06.05.95	8.18 ± 0.25	8.54 ± 0.24		32
12.05.95	8.48 ± 0.30			32
27.05.95	8.72 ± 0.20			34
30.05.95	8.79 ± 0.33			34
05.06.95	4.54* ± 0.95	5.65 ± 0.67	30	27
12.06.95	6.17 ± 0.55			28
25.06.95	6.20 ± 0.35			29
29.06.95	5.68* ± 0.85		20	28

Table 1. *(Cont'd)*

Date	Exhalation rates mBq m^{-2} s^{-1}		Rainfall in mm	Average ground temperature in °C
	Daily Average	Monthly Average		
1	2	3	4	5
02.07 95	5 60 ± 0.77	5 18 ± 1 14		27
08.07 95	5 35* ± 1 35		10	23
12 07.95	5 55 ± 0 95			22
14 07 95	5 46 ± 0 97			23
15 07 95	2.74* ± 1 45		50	22
25 07 95	6.38 ± 0 92			25
02 08 95	6 32 ± 0 25	5 97 ± 0 35		25
09 08 95	6 29 ± 0 28			24
16 08 95	5 96 ± 0 32			26
30 08 95	5 97 ± 0 38			25
31 08 95	5 35* ± 0 55		20	22
01 09 95	6 17 ± 0 45	5 28 ± 0 77		23
05 09 95	6 14 ± 0 93			24
06 09 95	3 86* ± 1 27		30	23
13 09 95	5 60 ± 0 86			22
24 09 95	5 28 ± 0 60			24
26 09 95	4 54* ± 0 98		20	23
30 09 95	5 38 ± 0 26			24
04 10 95	5 44 ± 0 36	4 62 ± 1.72		23
05 10 95	2 98* ± 1 82		50	22
06 10 95	2 22* ± 1 16		70	22
12 10 95	6 76 ± 0 94			23
24 10 95	572 ± 0 75			23
01 11 95	5.18 ± 0 67	3 26 ± 1 15		20
07 11 95	2.51* ± 1 45		40	20
08.11 95	1 76* ± 1 35		60	20
26 11 95	3 26 ± 0 83			22
30 11 95	3 58 ± 0 72			22
01 12 95	3 93 ± 0 24	4 42 ± 0.34		24
08 12 95	4 40 ± 0 36			23
26 12 95	4 45 ± 0.32			28
30 12 95	4 88 ± 0.41			27
01 01 96	4 64 ± 0.43	4 90 ± 0.47		27
11 01 96	4 65 ± 0 42			28
19 01 96	4 70 ± 0 48			28
25 01 96	5 59 ± 0 52			29
06.02 96	6 19 ± 0 26	6.65 ± 0.31		29
15 02 96	6 60 ± 0 32			29
25 02.96	6 78 ± 0 45			30
30 02 96	7 05 ± 0 25			31

* Rainy days

The radon exhalation rate depends to some extent on the ^{226}Ra content of soil. The mean value of ^{226}Ra around Mysore is 2–12.9 $Bq.kg^{-1}$. All India range is of the order 2.6–26.3 $Bq.kg^{-1}$ and world figure is 2.96–140.6 $Bq.kg^{-1}$ [9]. Activity of ^{226}Ra in Mysore region soil is comparable to figures found elsewhere. Diuarnal variation of radon exhalation is as shown in the Table 2. It is seen that, exhalation rate is almost constant during night and early morning but gradually increases reaching a maximum around 15.00 to 20.00 hours.

Table 2. Diuranal variation of radon exhalation rate [During January, March and April]

Time of Day (in hrs.)	Radon exhalation rate $mBq\ m^{-2}\ s^{-1}$		
	19.01.96	25.03.95	03.04.95
04 – 05	3.79	6.22	7.76
06 – 07	3.95	6.56	7.64
10 – 11	3.99	6.86	8.63
12 – 13	4.84	7.23	8.69
15 – 16	6.83	7.76	8.26
18 – 19	6.65	7.41	8.29
22 – 23	3.92	6.88	8.04
01 – 02	3.63	6.88	7.78

Diuarnal variation in the months of March and April is maximum (summer) and low in the month of January (winter). Usually inversion condition prevails and atmospheric pressures are usually higher than in summer. Probabaly because of this reason the exhalation rates are low in winter. It may be observed that the correlation between exhalation rate and ground temperature is decidedly better, the correlation coefficient '*r*' being equal to 0.85

Radon exhalation rate from soil in Mysore region is low, obviously due to low uranium content of the soil. The variation pattern is also as reported elsewhere. The values are low when compared to the global average values 15–20 $mBq.\ m^{-2}.\ s^{-1}$ [10].

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